THE OHIO JOURNAL OF SCIENCE

VOL. XXVIII MARCH, 1928 No. 2

# PRINCIPLES OF PLANT TAXONOMY, V.*

JOHN H. SCHAFFNER,
*Ohio State University.*

After studying the taxonomy of plants for twenty-five years the very remarkable fact became evident that there is no general correspondence of the taxonomic system with the environment, but as the great paleontologist, Williams, said in 1895: "environmental conditions are but the medium through which organic evolution has been determinately ploughing its way." Of course, the very fact that there is a system of phylogenetic relationships of classes, orders, families, and genera and that these commonly have no general correspondence to environment shows that, in classifying the plant material, we must discard all notions of teleological, utilitarian, and selective factors as causative agents of evolution.

The general progressive movement has been carried on along quite definite lines. The broader and more fundamental changes appeared first and are practically constant, and on top of these, potentialities or properties of smaller and smaller value have been introduced, until at the end new factors of little general importance alone are evolved. These small potentialities are commonly much less stable than the more fundamental ones and thus great variability in subordinate characters is often present in the highest groups. We must then think of the highest groups as being full of hereditary potentialities while the lower groups have comparatively few.

As stated above, there is a profound non-correspondence of the taxonomic system and the various orthogenetic series with the environment. The system of plants, from the taxonomic point of view, is non-utilitarian. The abundant adaptations of details to environment have no direct relation to the taxonomic

*Papers from the Department of Botany, The Ohio State University, No. 214.

system and do not run parallel with it. The same progressions take place whether a group is moving into the water or is remaining in the aerial environment. It is also self-evident that the most diverse taxonomic groups are adapted to and thrive in the same general environment. If there is, here and there, a correspondence, it is a mere coincidence, sometimes necessary for survival and sometimes not. Ecological adaptations, however, also appear in large groups of plants, as in the cacti and certain spurges, which fit well into a desert habitat although there is little similarity in their special fundamental morphology when compared with each other.

## The Determination of Lower and Higher Levels in the Series.

In any series, the high types can be distinguished from the low because the low have a less complex heredity and a less complex reaction system when compared with the higher types. The relative position can also be readily determined by considering the degree of divergence of two or more types of homologous organs of the individual, as by comparing the floral axes and their peduncles and the inflorescence axes with the vegetative axes; or comparing sporophylls with foliage leaves. In a primitive lycopod or an araucarian the floral axis is very little different from a vegetative axis; in a *Magnolia* there is an appreciable difference; while in a poplar or sunflower the difference is enormous. The same comparisons would hold true for the sporophylls and foliage leaves in these types. Often a progressive series extends for a great distance from low to high forms, giving unmistakable criteria for judging the relative degree of advancement of any species or group; as, for example, the progressive development of a more definite and prompt determination of the floral axis in the case of strobili and higher flowers. In finding comparative levels, the sporophylls are often of great value. In the lowest levels there is no essential difference between the characters of these organs and the foliage leaves, except that the former bear sporangia, as in many lower Polypodiaceæ; while on a higher level, as in *Onoclea* and *Pteretis*, *Equisetum arvense*, or *Lycopodium complanatum*, the angle of divergence is comparatively great; although not nearly so great as in an angiosperm. One can also compare the diversity and divergence of vegetative branches to determine comparative levels in the progressive series; as,

for example the simple branching system of *Lycopodium lucidulum* with the polymorphic branches of *Lycopodium complanatum*. A progressive series is evident when one compares *Lycopodium annotinum* without inflorescence with *Lycopodium clavatum* and with *Lycopodium complanatum*. The evolutionary advancement is evident at a glance. A similar more extensive movement of inflorescence developments is shown in the gymnosperm series: *Araucaria imbricata, Cunninghamia sinensis, Cryptomeria japonica, Taxodium distichum, Ephedia trifurca.* One can find similar progressive series in a large number of monocotyl and dicotyl groups. If we compare the flowers and clusters of *Araucaria bidwillii, Magnolia foetida, Prunus americana, Salix amygdaloides*, and *Leontodon taraxacum*, we can easily see that the order given represents a very decided series of evolutionary advancement, and a correct presentation of their relative positions as high and low, when compared with each other without any reference as to their direct relationships. The order given represents the proper sequence of higher and more complex hereditary natures in respect to the structures under consideration. The same sequence would be indicated if in each case we would compare the degree of divergence between the sporophylls and foliage leaves. The difference in character between the floral axis and its peduncle and an ordinary vegetative axis will also indicate comparative levels very well. The difference in *Araucaria imbricata* is very slight, in *Magnolia foetida* not very pronounced, while in such an extreme form like *Populus deltoides* it is very great. This means then that the *Populus* cell has a highly complex heredity which in one case can bring out a thick woody vegetative stem and in the other a delicate, thread-like herbaceous stem represented by the pedicel and inflorescence axis. Any one can understand the implication when he remembers that in the most primitive vascular plants, like a *Lycopodium lucidulum* or a simple fern, all the branches are exactly alike in their hereditary expression. Such estimations of the degree of divergence of homologous structures in the individual are in general a correct measure of relative position. A *Lycopodium lucidulum, Magnolia*, and *Populus* would receive exactly similar treatment if their relative positions were judged by the degree of determination expressed in their reproductive or floral axes. A large number of such progressive differences can usually be discovered and it must always be remembered that it is the summation

of all the fundamentally important evolutionary processes which determines the relative position of a plant in the absolute scale. A plant is sometimes very advanced in one character and quite retarded in another.

In plants with flowers, the degree of promptness of determination of the reproductive axis usually gives very definite evidence of relative position in the progressive scale as indicated by the following examples: Staminate cone of Strobilophyta,—*Araucaria brasiliensis*, 1000 ± stamens; *Araucaria excelsa*, 400 ± *Pinus strobus* 200 ±; *Podocarpus spicata*, 70 ±; *Taxus canadensis* 7 ±; *Ephedra trifurca*, 5; *Gnetum latifolium*, 1. Monocotyl hypogynous series, Alismatales,—*Echinodorus cordifolius*, *Alisma subcordatum*, *Tenagocharis latifolia*, *Triglochin maritina*, *Triglochin palustris*, *Scheuchzeria palustris*, *Potamogeton natans*, *Althenia cylindrica*, *Naias flexilis*, *Zostera marina*. An hypogynous dicotyl series,—*Magnolia foetida*, *Ranunculus septentrionalis*, *Caltha palustris*, *Geranium maculatum*, *Agrostemma githago*, *Claytonia virginica*, *Anychia canadensis*, *Corispermum hyssopifolium*, *Monolepis nuttalliana*. An epigynous dicotyl series,—*Philadelphus coronarius*, *Nuttallia decapetala*, *Mentzelia oligosperma*, *Chamaenerion angustifolium*, *Ludwegia sphaerocarpa*, *Circaea lutetiana*, *Hippuris vulgaris*. All these lines and many others show the same remarkable orthogenetic series which is plainly the result of a continuously more prompt determination of the floral axis. This movement is even evident to some extent in the strobili of the Lepidophyta and Calamophyta. Such movements show no correspondence with the environment and all teleological explanations, as selective value, interaction with the environment, or use and disuse have no scientific meaning, but belong to the childhood stage of biology. Correct ideas in regard to the evolutionary process are of the greatest importance in arriving at a proper phyletic taxonomy.

In the vegetative system there is a progressive movement in complexity of the branching system from the completely unbranched to a very extreme system and then a specialization from a moderately branched system to a comparatively simple condition, usually with the development of herbaceousness, and a progressive development of vegetative determination in some or all of the terminal buds of the plant. Commonly there are closely related woody and herbaceous forms in the same group, and larger groups are not to be segregated, merely on the basis

of woodiness and herbaceousness. These characters for the most part merely represent levels which are attained in a multitude of cases.

Although the secondary sexual condition is not manifest in the sporophyte until the heterosporous pteridophyte stage and the bisporangiate flower is carried through to the very highest group of dicotyls, nevertheless there is, all along the line, a progressive movement in very many branches from this condition to complete dieciousness. The movement is from sex determination at the end of the sporophyte ontogeny to earlier and earlier stages of the ontogeny until the limit is reached in the egg. The four general steps in this progression are: first, male and female determination on the same sporophyll; second, bisporangiate flowers, in the angiosperms with stamens below and carpels above; third, the various types and degrees of moneciousness; and fourth, the complete diecious condition which is, however, also developed in various degrees of completeness and intensity. There are exactly similar progressive movements in the gametophytes of the Homosporous Metathallophyta.

Progressive levels of complexity are also indicated by the diversity of leaf forms. In the lowest vascular plants like ferns and lycopods, there are but two types of leaves, foliage leaves and sporophylls, with practically no vegetative difference between the two. With the introduction of heterospory, there are at least three kinds of leaves. In cycads there are four kinds, in the lower Araucarians there are but three general kinds of leaves, while in *Pseudotsuga* there is a general tetramorphous condition. In the extreme Pinaceae, as in *Pinus*, there are beside the special juvenile leaves, two kinds of sporophylls one kind of foliage leaves, one kind of scale leaves on the dwarf branches, and two kinds of scale leaves on the ordinary branches. In some species these various categories will divide up into further subordinate types. In the gymnosperms the condition of the cotyledons follows along in the same general sequence. The lower gymnosperms have two cotyledons normally, while the number rises rapidly in the Pinaceæ until it reaches a dozen or so in some pines. The development of specializations in the embryo is even more remarkable and attains its extreme expression in the bizarre embryogeny of the pines and certain of the Juniperaceæ. Thus these parallel movements in the development of complexity of the hereditary

potentialities are correct criteria for judging the relative positions of the forms to be classified as high and low. Now it is true that occasionally a group may have retained with little or no change some very primitive structures in some part of its anatomy. Such a condition can, however, not be used to pull a species or group down to the lower level. Because a man may have retained the potentiality to produce gill-slits, either in the embryonic stage or up to the mature condition, does not put him on the level of a fish. The complexity of the hereditary potentialities as a whole will give the proper basis for a correct determination of any given case.

In the smaller branches of the phyletic system there are often quite definite orthogenetic movements resulting in definite orthogenetic series. In such cases the arrangements are to correspond to these movements. The sequence from low to high, from simple to complex, will then be properly indicated by the classification. Usually we cannot tell the actual sequence of origin of one form from another in such an orthogenetic series unless paleontological evidence is available. But the fact of the existence of an orthogenetic series is more important than speculations about its causes or the order of derivation of the members of the series.

### The Definite Limits of Various Orthogenetic Series

It is evident, both from a consideration of various fossil groups and from a study of taxonomic series of living species, that many evolutionary movements come to a definite limit or end, beyond which no further advance is possible. In fact, practically all of the major movements are of this nature. The evolution of the time of sex determination proceeds backward through the ontogenetic cycle until it has progressed through both the gametophyte and sporophyte where the limit is reached in the diecious condition, when the circle is completed. The development of the flower progresses from the very slow determination of the primitive strobili until the highest stage is reached in the epigynous flowers in which the central growth of the flower axis stops before any floral parts have even made their appearance as incepts. In some of the higher Andropogoneæ a curious box is developed containing the grain. This box becomes more and more perfect until the extreme is reached in teosinte. In the Liliales the most primitive species are large trees, and many of the lines progress by successive steps

to smaller herbaceous forms, with the vegetative stem finally completely underground and only a few millimeters in height, all of the leaves and the flower clusters coming from below the surface. The dropping of stamens and other parts through the evolution of zygomorphy proceeds in the same way. Everywhere at the extreme limits, the flower has by successive stages arrived at the condition where only two or one stamen are left. The limit of development of the syncarpous gynecium is a unilocular ovulary with two stigmas or only one. The progressive limit in the relationship of sporophyte to gametophyte is the seed plant condition where the gametophyte is parasitic in the sporophyte and the sporophyte embryo is parasitic in the gametophyte. The recognition of these limits is of very great importance in taxonomic studies. Not only do the higher types approach evolutionary limits but in some cases "over adaptation" is brought about. The structure is carried far beyond the limits of practical utility, as for example, the parachute development in the fruit of the dandelion and others of the same family. The highly evolved plant is full of hereditary potentialities and thus often has enormous possibilities for minute variations when compared with the lower forms. The lower form has more of the primary heredity and usually little of the superficial while the higher contains all the primary properties and in addition a host of superficial and insignificant factors. These superficial factors are commonly transcient or mutable, hence in many such high forms mutations are continually appearing. On the other hand some limits become remarkably stable.

## Extraordinary Developments Appearing at the Ends of Extreme Phyletic Branches.

From what has been said in the preceding paragraph, it is evident that many extraordinary bizarre, and extreme developments will commonly be found at or near the evolutionary limits. Among such peculiar systems, the following are noteworthy: In *Azolla* the microsporangium develops a number of massulæ containing the spores and on the surface of these massulæ numerous anchor-like processes or glochidia are present. The higher Selaginellas present a very peculiar stem structure. There are tubular air cavities and the vascular bundles extend through the center of the tubes and are connected with the

ground tissue by means of filaments of cells or trabeculæ passing across from the outside of the bundle to the wall of the air cavity. In the higher Pinales there is a remarkable system of multiple embryos with unusual suspensors as well as an extreme development of the number of cotyledons. In the *Pinus* embryogeny and also in *Biota*, we have a type of embryo development which is not duplicated in any other vascular phylum. In the Gnetales, the leaves of *Tumboa* present an extreme and peculiar system. The only two foliage leaves that the plant produces continue to grow from the base as long as the plant lives until they are ribbons, yards in length. The beginning of such a leaf development is also present in Pinus which belongs to the same phylum. But in even the most extreme cases of this character in *Pinus*, the basal growth continues for but a comparatively short period and the needles rarely reach a length of two feet. In the higher Helobiæ, *Vallisneria* has developed a remarkable method of pollination in that the minute submerged staminate flowers are separated from the inflorescence to float on the surface, where they come in contact with the stigmas of the capellate flowers, which have been brought to the surface on an enormously long, spirally coiled peduncle. In the region of the highest grasses are the Indian corn (*Zea*) with its extraordinary stigmas, ear, and husks, and teosinte (*Euchlaena*) with its caryopsis packed up in a wonderfully constructed "alabaster" box, as recounted above, along with elongated stigmas and husks much like in its near relative. In the highest monocotyls, the orchids, one finds a host of remarkable developments, in the pollen masses, bizarre perianths, and often exceedingly peculiar leaf structures. Near the top of the Thalamifloræ are the violets, the highest of which present us with the problem of showy and cleistogamous flowers to the confounding of both Lamarckian utilitarians and Darwinian selectionists. These cleistogamous flowers as well as parthenogenetic developments of various types appear in the higher regions of many subordinate phyla. In the extreme Piperales we meet with 16-celled female gametophytes with their remarkable developments of multiple nuclear fusions, in one species of *Peperonia* the definitive nucleus being formed by the fusion of 14 polar nuclei. In the specialized Amentiferæ, as in *Casuarina*, *Ulmus*, etc. chalazogamy has developed, representing the extreme condition of the evolution of the parasitic ability of the pollen tube. At the end of the Gentia-

nales stand the Milkweeds with extreme pollen specialization in evidence, again simulating the development in *Azolla* and the orchids. The method of pollination evolved in our common species, *Asclepias syriaca* is so efficient that with an ideal environment, with an abundance of insect visitors at hand, a milkweed flower has one chance in about 80 of being pollinated and thus contributing its service in the perpetuation of its race. The mints stand at the top of their order and the salvias at the top of the mints in progressive specialization of the flower. Now in the extreme species of *Salvia* two fertile half stamens are present in the flower which are so developed that they form a perfect brush and lever arrangement for spreading the pollen on an insect's back. This apparatus is one of the most remarkable in the plant kingdom, and the lucky *Salvia* would certainly be envied by its unlucky relative, *Asclepias*, if plants were able to experience envy at the good fortune of their neighbors. Near the top of the Scrophulariales stand the Bladderworts not only with highly evolved flowers but with their remarkable bladders or aquatic traps. Without multiplying examples further this list can be completed by a reference to the dandelion (*Leontodon taraxacum*) which stands about at the top of the plant kingdom. This plant has developed a type of parthenogenesis through the aquisition of some hereditary potentiality which interfers with the proper primary sexualization of its synaptic chromosomes; yet we all know how rarely a dandelion flower fails to set seed. Along with many of its relatives, the dandelion has evolved a peculiar, elongated neck at the top of its fruit which together with the pappus (which in itself is a remarkable structure at the end of calyx evolution) forms a most efficient parachute. Thus the dandelion, which has such a severe struggle to maintain itself in our front lawns and roadsides is able to send its offspring a hundred miles or so away from the paternal home where another favorable lawn or roadside may be available in which the child may possibly survive in a cruel and untoward world!

Now the recognition of these special developments is one of the most important exercises in taxonomy, because the more primitive members of any main or subordinate phylum rarely show extreme specializations except perhaps in very unimportant details. Curiously enough some of the conditions listed above have in the past been regarded as indicating primitive conditions, as the presence of chalazogamy in *Casuarina*, the extremely

advanced floral structures of Taxales, the multiple embryony and multiple cotyledons of Pinales, and the highly complex condition of *Zea* and its relatives. In fact there are yet few plant taxonomists that do not still place Zea at the base of the grass series. According to such a scheme, Indian corn must have been a special creation, without father, without mother, including all specializations and complexities, which after its placement on the earth gave rise to the series of lower and lower and more simple forms by devolution, each main step taken in the family leading nearer to the simple starting point of the lowest vascular plants. It is truly remarkable that such crudity of scientific concepts could be perpetuated until the present day and still be followed as the authoritative and orthodox faith of most of the taxonomists the world over. The older taxonomies, based on the old crude morphological conceptions and the teleological explanations of Lamarck and Darwin of the causes of evolution, as well as some of the newer systems which have not been emancipated from these notions, are so far from the reality that one actually finds that an entirely new beginning must be made if taxonomy is to be, as it should be, a systematization of our knowledge of the evolution of plants and a picture of the actual relationships. The new patch cannot be put on the old garment. The old bottles will not hold the new wine.

## Distinguishing Phyletic Segregative Characters.

To distinguish fundamental segregative characters from progressive or merely detailed specializations is one of the main difficulties in taxonomy. As soon as one has advanced but a short distance in systematic botany, he is able to tell at a glance almost any of the thousands of members of such great families as, the sedges, grasses, orchids, legumes, mints, or composits. It must thus be that through all the multitudinous mutations which have resulted in subfamilies, tribes, genera, subgenera, species, and varieties something has remained which has not changed at all or only to such a slight degree that it is still recognizable. One of the chief exercises in phyletic taxonomy, therefore, is to ascertain these fundamental potentialities and characters, which because of their inherent stability give us our taxonomic system.

## Independence of the Various Mutative Movements.

Although there is more or less parallelism in all movements going on in a phyletic line in a general way yet one series of possible advances may remain stationary while another advances rapidly even to the extreme limits. Thus it often happens that primitive and advanced characters appear side by side in the same species or group. This fact causes much confusion. There are also important progressive movements which originate in independent phyla at very diverse levels and in very diverse biological systems, in diverse environmental conditions. The origin of the flower or determinate reproductive shoot is of this nature. It appears in the homosporous level in two phyla while there are heterosporous pteridophytes which are entirely indeterminate, and among the gymnosperms, although a strobilus is mostly present in the living species, yet *Ginkgo* has come to a high evolutionary level with no determinate axes whatever.

## Parallelism.

The parallel developments of both large and small degree are a constant source of uncertainity in taxonomy. Duplicate evolutions in different phyletic series are to be found in enormous numbers and frequently give rise to striking mimicries which have played such a prominent part in teleological explanations. But unfortunately for these crude utilitarian hypotheses, the duplications commonly occur without any relation to time or place, and even without similarity of ecological conditions. The older conceptions of selective mimicry belong to the same category as children's fairy tales, witch stories, and mother goose prodigies.

Parallelism necessitates distinguishing between characters that are segregative in kind, and characters which are merely corresponding stages in an orthogenetic series. For example, Orchidaceæ, Hydrocharitaceæ, Onagraceæ, and Campanulaceæ all have characteristically epigynous flowers, but the epigynous character which they have in common does not at all indicate relationship, but merely similarity of phylogenetic level. In the past, and to a large extent even in the taxonomic systems in vogue at the present time, such conditions are supposed to indicate relationship, as the character of the corolla, which is used to divide Dicotyls into apetalæ, choripetalæ, and sympetalæ, the apetalous forms being assumed to be primitive; but

one can find apetalous groups even among the Compositales. These three characters result from the progressive shortening of the floral axis, the choripetalous condition being the most primitive and the sympetalous and apetalous conditions more advanced stages due to earlier determination. In contrast to such characters that only indicate similar orthogenetic levels, true segregative characters are indicated in the fundamental branching systems of Lepidophyta and Ptenophyta. The first have dichotomous branching and the second monopodial branching. Such a difference is a true phyletic segregative difference between the two phyla, because the branching is brought about in a fundamentally different way in the two cases and the one is not higher than the other nor a derivitive from the other but only a different way of accomplishing the same thing, namely, an increase in the number of growing buds and axes. Each system may and does evolute from an exceedingly simple branching system to a very complex one.

## Recapitulations.

The partial or complete suppression of hereditary characters through the addition of new ones is of great interest to the taxonomist. For if such characters can be expressed for only a short period either as a normal process in the ontogenetic cycle or through the influence of some unusual environment which permits the suppressed potentialities to come into play, important evidence of obscure relationship may be obtained. The recapitulation may occur in the embryonic or juvenile phase of development, in a certain period of the mature ontogeny, or at the very end of the ontogenetic cycle. Many cases of undoubted recapitulations in the juvenile phase are known, as in some Acacias with phyllodes in the mature condition. The juvenile form regularly develops several, typical, compound leaves of the *Acacia* type. Recapitulation is seen at the end of the ontogenetic cycle in many flowers. In the grasses the vegetative phase develops a two-ranked leaf condition, but the ultimate floral axis invariably returns to the primitive three-spiral condition. In *Cabomba*, dissected leaves appear on the growing plant but at the very end, before the flowers appear, several minute vestigial, peltate leaves usually develop to proclaim its relationship to *Brasenia* and *Nelumbo*. In *Equisetum*, the leaves are degenerate and form a united sheath but the sporophylls appear as distinct structures, which is plainly a return to the condition of the *Equisetum* ancestors

with normally distinct leaves. In some plants recapitulations can be brought about by merely disturbing the normal functional gradients. In hemp, the several rejuvenations which can be brought about are always follwed by the appearance of simple leaves, in the first stage of the new growth cycle in the same way as when the plant is developing from the seed. On the other hand, just as supressed heredity may normally show only in the determinate, senile condition of the ontogeny so new heredity may be added to modify the character of the embryo or the juvenile phase. The embryo is subject to the same kinds of phylogenetic changes as the mature plant. Past opinion to the contrary has sometimes resulted in decidedly incorrect speculations as to relationships based on superficial similarities or dissimilarities of the embryos. But recapitulation when carefully considered is often an important aid in determining correct relationships. Recapitulation is made possible by the fact that most of the important new heredity is laid down on the old and may supress the activity of the old or limit its activity to a special phase of the ontogenetic gradient. In some cases important new heredity may not show until near the end of a determinate gradient, as in the spikelets of *Cyperus* which have two-ranked glumes and flowers while the vegetative phase of the plant continues in the more primitive 3-spiral condition.

### Transformed Organs.

How are we to conceive of the significance of a change in organs when, for example, the blade of a *Botrychium* develops one or more sporangia, which normally appear only on the stalk of the special sporangiophore? In the past morphology much speculation was based on such abnormalites since the plant was usually thought of as being built up of a certain number of homologous and diverse parts, just as a house is built up of boards, bricks, stones, etc. In the case cited the abnormality would have no more significance than that the functional gradient was disturbed through one cause or another and the cells brought into the condition where reproductive sporangium factors are brought into play. If the leaf normally present on a tulip peduncle is partly or completely transformed into a petal-like structure, it does not mean that the tulip formerly had petals where it now has leaves but merely that the functional gradient in the given peduncle arrived a little earlier at the condition in which petal factors normally come into play.

By disturbing the functional conditions in hemp it is easy to throw the sex of the carpellate plants to maleness in some branches and of the staminate plants to femaleness. In such cases it happens quite frequently that stamens appear with well-developed stigmas projecting from their tips. This does not mean that the ancestors of the hemp had stamens with stigmas. On the transition from vegetative to flower expression in a grass the two flowering glumes are developed, the lemma with a central midrib and the palet with two ribs. This does not mean that the palet represents two ancestral leaves or even sepals but simply that in the present system the floral axis is so shortened that the lateral organs appearing on the transition zone between the two-step to the three-step expression, partake of both conditions because the one set of factors has not become quiescent before the other is becoming active.

## Interpretation of Vestiges in the Flower.

Vestiges may appear in the flower due to vegetative reduction. Frequently the sporophylls at the tip of the cone are vestigial because the factors of determination come into play before the structures have had time to reach full development, as is to be seen prominently in *Equisetum* cones and in the carpellate cones of *Pinus*. Structures reduced through one cause or another may also assume special characters as the reduced glands or vestiges in the lower part of the andrecium of *Geranium*, *Pelargonium*, *Oxalis*, and *Linum*. The most prolific source of vestigial sporophylls in the flower is caused by displacement of the time of sex-determination. Since the primitive Angiosperm flower is bisporangiate with the secondary male state in the lower part of the axis and the secondary female state above, it follows that when the sex is determined somewhere below the flower, the given sexual state will then inhibit the development, to a greater or less degree, of the opposite type of sporophylls. A female state in the entire flower will interfere with normal stamen development and a male state will interfere with normal carpel development. Generally speaking, if the change is present in a low type of Angiosperm flower the vestiges will be large while in a high type they are frequently absent entirely. In some cases the stamen vestiges may be present and the carpels entirely suppressed, while in others the carpel vestiges may be present and the stamens completely suppressed. These vestiges, due to displacement of the time of sex determination, are commonly

of great importance in showing relationships, or lower and higher evolutionary levels. In some cases of moneciousness or dieciousness, the flowers in one sexual state are on a much lower evolutionary level than those in the other sexual state, and these conditions may be of service in determining relationships. Of course, the complete suppression of the opposite set of organs in one flower and not in the other, as mentioned above, would come into this category. Very extreme cases are represented by *Cycas*, *Hydrocharis*, and *Cocos*. In *Cycas* the carpellate plant is a flowerless plant having an indeterminate reproductive axis, while the staminate plant is a flowering plant with definite, determinate staminate axes, or cones. In *Hydrocharis* the staminate flower is hypogynous with more numerous sporophylls and apocarpous carpel vestiges while the carpellate flower is completely epigynous with a syncarpous gynecium. In *Cocos* the staminate flowers have a nearly completely apocarpous andrecium of three vestigial carpels while the carpellate flower has a completely syncarpous gynecium. A common source of vestiges is found in the telescoping of vegetative and reproductive expressions associated with the progressive contraction of the floral axis. These vestiges are abundant at the base of the angiosperm flower as, for example, in the six or fewer perianth bristles of *Scirpus* and *Eleacharis*. Such imperfect developments of a less extreme type are prominent at the base of the carpellate cones in the higher species of *Pinus*.

### Hybridization in Extreme Groups.

In some of the more extreme genera, there is not only much mutation but the functional and morphological conditions are such that there is no barrier to free hybridization. This results in an almost endless multiplication of combinations and of frequent irregularities as well. The group of species or even the single species appears to break up into a fine spray of forms and combinations of characters. Such genera are represented by *Crataegus*, *Oenothera*, *Rosa*, *Salix*, *Hieracium*, *Zea*, etc. These complexes of species and varieties have been the despair of systematists as well as the seducers of the philosophically inclined geneticists and evolutionists, who have seen in such extreme conditions the very basis of evolutionary activity and genetic foundations. Evidently a special treatment of such genera and species would be desirable since they do not fit very well into the straight jacket of ordinary taxonomic procedure.

## Classification and Chromosomes.

Larger and smaller groups commonly have a base number of chromosomes with haploid and diploid complements because of the processes of fertilization and reduction. So long as the number of chromosomes is similar there is no mechanical difficulty in perpetuating the results of a hybridization. But if the haploid complements are unequal in number, irregularities are the inevitable result, because in synapsis it is impossible to have a complete mating even though no incompatibility to pairing of chromosomes is present. The cytological study of a complex species or group of species is thus of great practical value. On the other hand, the mere shifting of chromosomes or the multiplication of the base number is of no fundamental taxonomic or evolutionary importance, although such mutation has probably been going on from the beginning of sexuality. Normally a proper balance is attained with efficient survivial value, and the same base number may be commonly present in a wide diversity of related forms. The real evolution of plants which has resulted in the taxonomic system was through the addition of new potentialities in the structure of the protoplasm itself, presumably mainly in the structure of the chromosomes. The mere multiplication of the base number of chromosomes from the primary haploid and diploid normal to a triploid, tetraploid, or even greater polyploid number has little or no effect on the process of speciation, to say nothing of the great fundamental progressive and segregative processes which brought about the taxonomic system. Miss Blackburn has recently shown that a 16-ploid race of *Silene ciliata* can hardly be distinguished from a tetraploid race. The mere accumulation of chromosomes of like potentialities has no bearing on the evolution of new potentialities. It is the assimilative potentiality of the chromosome that must be changed. If such mutative changes have gone on or are continuing and no incompatibility exists to interfere with the primary sexual processes of either the normal union of the gametes or the synapsis of the chromosomes then hybridization with diverse mixtures of chromosomes may give rise to many new combinations with favorable selective value, resulting in diverse combination varieties, which would otherwise probably never come into existence. The supposed speeding up of mutations reported from the irradiation of certain plants and animals, although they may actually show a specific effect, which is

not at all certain since unfortunately the experiments have so far been tried only on the extremely complex species of *Drosophila* and *Nicoteana*, mean nothing fundamental either for evolution or taxonomy. Such claims of causing "evolution" or "speeding up" of the evolutionary process are not to be considered seriously, since the taxonomic system is of such a nature that no such simple and artificial influence is adequate to explain even the smallest steps of the process that brought it into existence. People who make such claims of causing or speeding up the evolutionary process simply show their complete innocence of the taxonomic system and the movements which are known to have been in operation during paleontological times. Such specious claims are of no value to the taxonomist because if even a chromosome can be injured or modified so as to destroy some of its important structures in which certain potentialities exist, such a fact will have no bearing on the serious study of ascertaining relationships of higher and lower order or of discovering the progressive evolutionary movements which have ploughed their way through the geologic eons.

## Serum Reactions.

One of the most remarkable discoveries in the realm of taxonomy in recent years is the fact that plant relationships can be correctly determined by means of serum precipitates. For this great development we are largely indebted to Mez of Koenigsberg. It is well known that in some plants the ordinary morphology is so obscured through reduction or specialization processes that a proper placement in the taxonomic system becomes very doubtful. In such cases, serum reaction determinations become exceedingly valuable and in fact indispensable. The serum method can also be used to check up on the phyletic system that has been developed through a study of the morphology, physiology and chemistry of plants in the classical way. The work accomplished so far confirms in a decided manner the phylogenetic relationships as worked out by Bessey, the writer, and others working purely with the morphological, physiological, and paleontological indications. Of course, the serum reactions probably have their obscurities as well as the morphological systems and are not to be taken as final arbiters in taxonomy. The practical taxonomy will always be built on a morphological foundation, since this is the easiest method of approach and is the only one that is commonly convenient to use.